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[*Received August 16, 1971; revised August 9, 1972*]

Reply [1,2]

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The source term, $-\mathbf{V}\cdot\nabla\phi$, in the kinetic energy equation can be expressed as

$$-\mathbf{V}\cdot\nabla\phi=-\nabla\cdot\mathbf{V}\phi-\frac{\partial\omega\phi}{\partial p}-\omega\alpha.$$

While the conversion term, $-\omega\alpha$, may be regarded as the release of available potential energy, $-\nabla\cdot\mathbf{V}\phi$, and $-\partial\omega\phi/\partial p$ may be regarded as the redistribution terms required for the released energy to finally appear as the actual generation of the kinetic energy in the cross-isobaric motion.

My paper (Kung 1970), referred to by Gordon, presented a latitude-height cross-section of the $-\mathbf{V}\cdot\nabla\phi$. The distribution of $-\mathbf{V}\cdot\nabla\phi$ is markedly different from that of $-\omega\alpha$ as we generally envision it. While we have large positive $-\mathbf{V}\cdot\nabla\phi$ values to the south and north of middle latitudes in the upper troposphere, and also generally in the lower troposphere, we find a significant, negative $-\mathbf{V}\cdot\nabla\phi$ in the middle and upper troposphere of the middle latitudes. This negative area of $-\mathbf{V}\cdot\nabla\phi$ is approximately the region where we expect the maximum $-\omega\alpha$. In a subsequent paper (Kung 1971), the adiabatic generation and destruction of the kinetic energy were examined separately for the zonal and meridional motions of the atmosphere. The results show that, at the lower latitudes, kinetic energy is produced by the meridional motion and destroyed by the zonal motion; while, in the middle and higher latitudes, kinetic energy is destroyed by the meridional motion and produced by the zonal motion. It is also significant that, despite the general smallness of the meridional wind, the magnitude of $-v(\partial\phi/\partial y)$ is comparable to that of $-u(\partial\phi/\partial x)$ and plays an important role as a source term in the kinetic energy balance. These examinations of the latitude-height distribution of the source term, $-\mathbf{V}\cdot\nabla\phi$, indicate the importance of the production of the kinetic energy in Hadley cells and destruction in Ferrel cells. The next logical step appears to be a study of the linkage between $-\omega\alpha$ and $-\mathbf{V}\cdot\nabla\phi$.

Computation of the "dissipation" term, E, as the residual term in the kinetic energy equation will remain the theoretically valid means for discussion until we become certain of the dissipation mechanisms involved. The dissipation in the planetary boundary layer usually is computed to be somewhere between 1 and 2 $\mathrm{W\cdot m^{-2}}$, depending on the boundary layer models and climatological data employed. The values listed by Gordon obviously fall in this range. As he has indicated, the dissipation in the free atmosphere, as obtained as the residual term, is considerable and its magnitude is crucial in discussing the balance of atmospheric energy.

However, it must be stressed here that the dissipation, E, obtained as the residual term with large-scale synoptic data is nothing but the sink term of the large-scale kinetic energy balance. This is the kinetic energy removed from the grid-scale for eventual viscous dissipation. The linkage between this "sink" and eventual viscous dissipation is an open question. I do not think the planetary boundary layer can have dissipation of more than 1–2 $\mathrm{W\cdot m^{-2}}$—all available boundary layer models seem to predict that no more energy could be dissipated in the boundary layer with the prevailing vertical wind shear in that portion of the atmosphere. In addition, the vertical transport of kinetic energy across the top of the boundary layer is obviously negligibly small. Thus, the dissipation mechanism associated with a significant sink term in the free atmosphere shall be found in the free atmosphere. The recent studies of clear-air turbulence as discussed by Trout and Panofsky (1969), the mechanism related to cumulus convection as suggested by Gray (1970), and subgrid-scale energy analysis by McInnis and Kung (1972) may be mentioned as studies relevant in this regard. In studies of the dissipation mechanism, the kinetic energy transport by the subgrid-scale motion will be the critical point in analyzing the energy budget.

[1] The research discussed in this publication was supported by the Atmospheric Science Section, National Science Foundation, under NSF Grant GA-15952.

[2] Contribution from the Missouri Agricultural Experiment Station, Journal Series No. 6213

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[*Received August 16, 1971; revised October 14, 1971*]

UDC 551.507.362.2:551.576.1:551.515.22(084.1)(94)"1972.04.16"

PICTURE OF THE MONTH

Real Time ESSA 8 APT Tracked Over Australia Received at Florida Over 11,000 Miles Away

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The ESSA 8 Automatic Picture Transmission (APT) subsystem consists of a camera and an FM transmitter designed to broadcast television pictures of the cloud cover *below* the satellite during daylight. During the recent Apollo 16 lunar mission, ESSA 8 APT photographs taken over Australia during daylight were obtained in Florida real time at night. This acquisition was made possible by means of the NASA/Apollo communication system. The NASA Orroral tracking station near Canberra, Australia, tracked ESSA 8. The signal was relayed to Cape Kennedy Air Force Station (Detachment 11, 6th Weather Wing) through Goddard Space Flight Center at Greenbelt, Md. The photographs were processed on a Muirhead 115B recorder,[1] gridded geographically, and interpreted by Air Weather Service satellite meteorologists at Cape Kennedy.

The ESSA 8 photographs (fig. 1) were then used to brief the pilots of the Apollo Range Instrumented Aircraft (ARIA), who were assigned to collect telemetry data from the Apollo spacecraft near Australia during the crucial "translunar injection" maneuver. The ARIA command post and its sophisticated communication center is located near Cape Kennedy at Patrick Air Force Base, Fla., where Detachment 11 personnel brief the decision makers in posititioning these modified KC–135 aircraft. Therefore, high quality, geographically gridded, real time meteorological satellite data is extremely important, particularly over sparse data areas.

On Apr. 12, 1972, 4 days before the Apollo liftoff, the ESSA 8 imagery indicated the presence and precise location of two tropical storms, Gail and Faith, potentially threatening the ARIA mission. Prior and subsequent ESSA 8 photographs, along with conventional meteorological data, indicated that these storms would no longer be a factor by launch day. At 0120 GMT on April 16, the final ESSA 8 transmission, before the translunar injection, confirmed the predicted clear skies over the vital area. The flawless launch and translunar injection of Apollo 16 are now, of course, history.

[1] Mention of a commercial product does not constitute an endorsement.

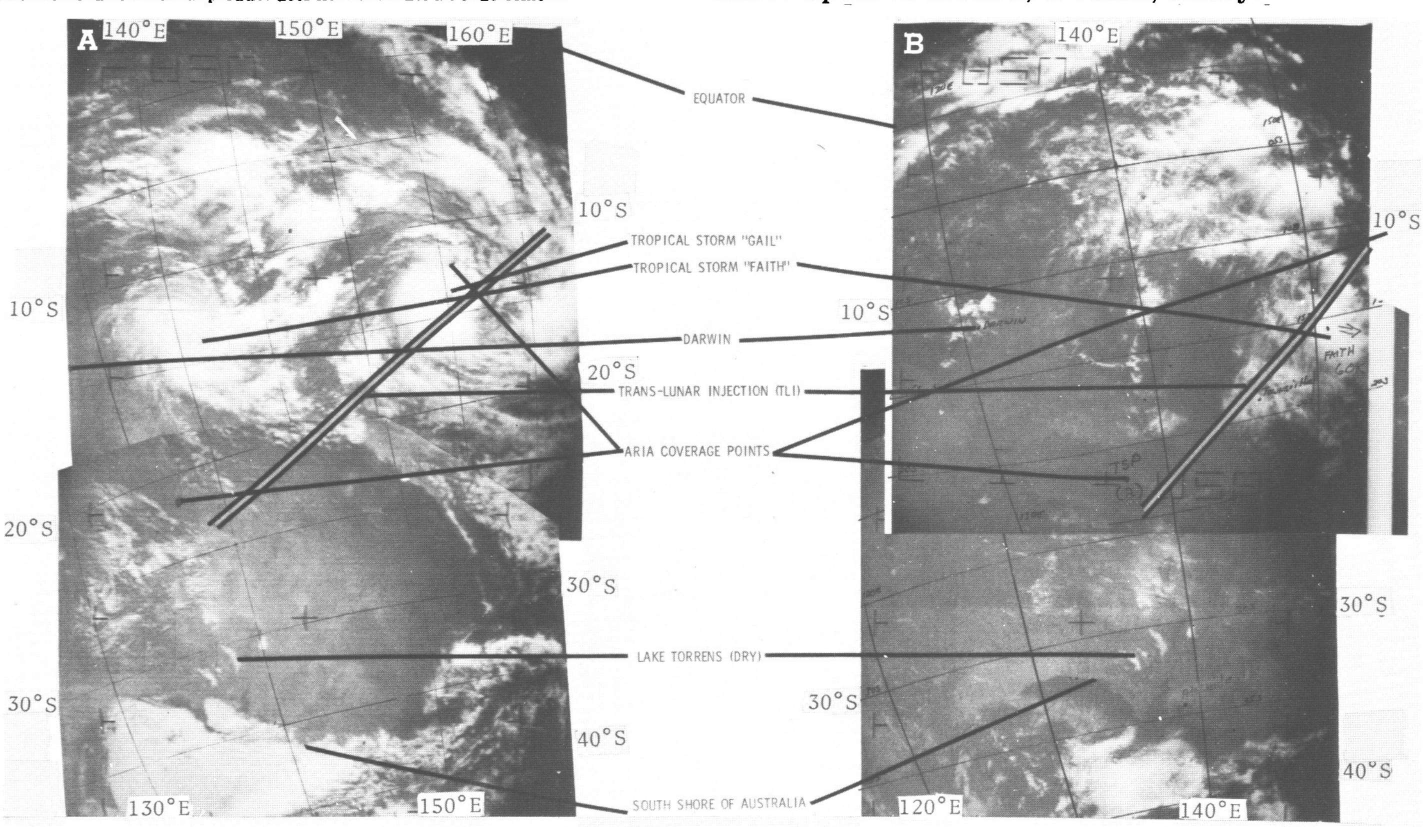

FIGURE 1.—ESSA 8 weather satellite photographs for (A) 2213 GMT Apr. 12, and (B) 0120 GMT Apr. 16, 1972 transmitted in real time from the NASA Orroral tracking station in Australia, to Goddard Space Flight Center, Md., to Cape Kennedy, Fla.